United States Patent [19]

Raffaelli et al.

[11] **3,774,077**

[45] **Nov. 20, 1973**

[54] **ELECTRICAL IGNITION APPARATUS**

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[73] Assignee: **International Telephone and Telegraph Corporation,** New York, N.Y.

[22] Filed: **July 8, 1971**

[21] Appl. No.: **160,827**

[52] **U.S. Cl.** **317/98,** 219/270, 219/552, 431/262

[51] **Int. Cl.** **F23q 7/10**

[58] **Field of Search** 317/79, 94, 98; 219/270, 552; 431/66, 262, 263

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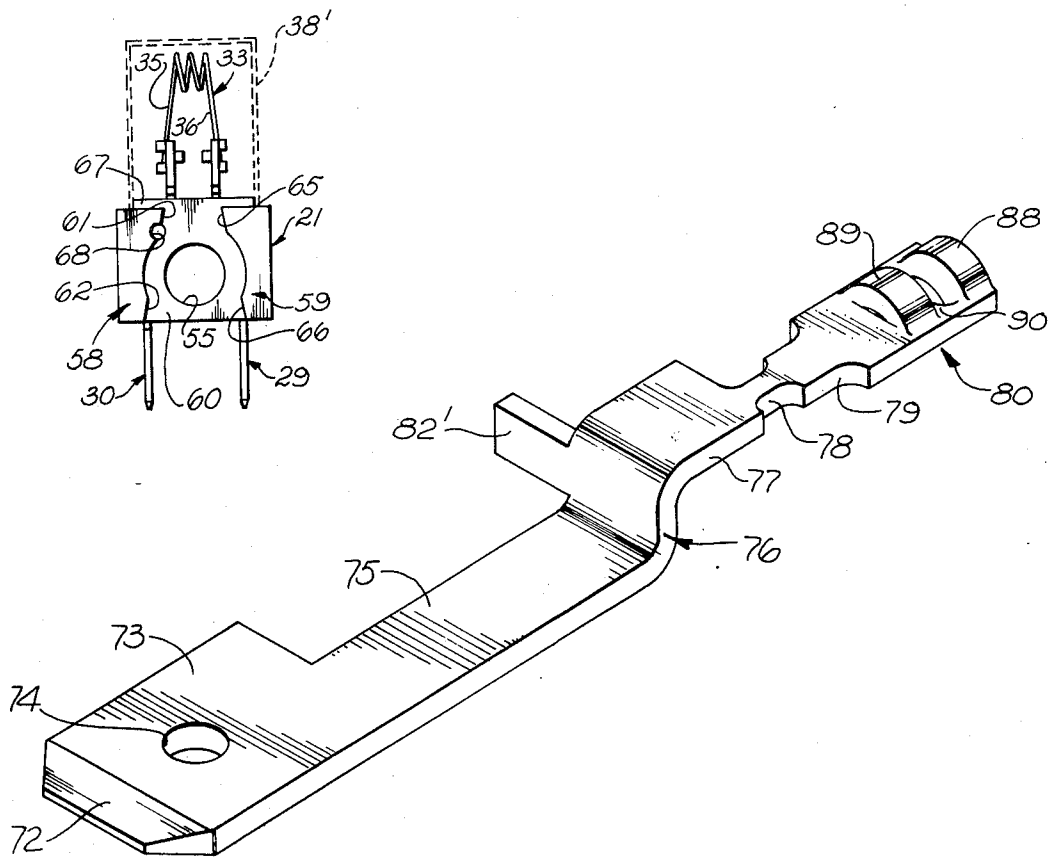
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Primary Examiner—Volodymyr Y. Mayewsky
Attorney—C. Cornell Remsen, Jr. et al.

[57] **ABSTRACT**

Electrical apparatus including a resistance wire ignitor for gas ranges or otherwise wherein the wire is made of molybdenum disilicide ($MoSi_2$). The $MoSi_2$ is very brittle, but has an exceedingly long life. The $MoSi_2$ may have a useful life well over 18 months, continuous use in an oxidizing atmosphere, as compared to 3 days continuous use for platinum under the same conditions. A number of problems were solved according to this discovery. Shock resistance was improved by use of dead soft electrical connectors having necked down portions to take a set rather than damage the brittle wire. A good 310 stainless steel connector to wire bond was discovered. The bond is made with an alloy of 18 percent nickel and 82 percent gold. The ignitor also has a snap-on shield.

22 Claims, 15 Drawing Figures



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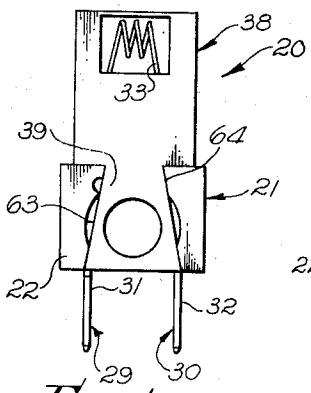


Fig. 1.

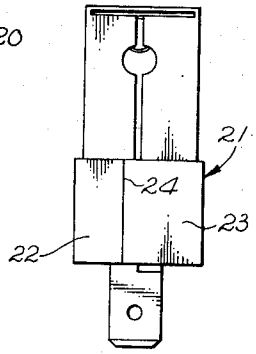


Fig. 2.

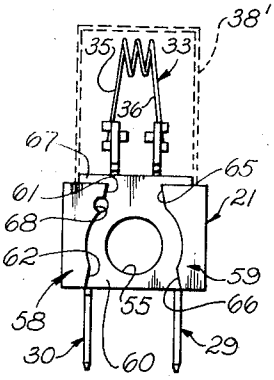


Fig. 3.

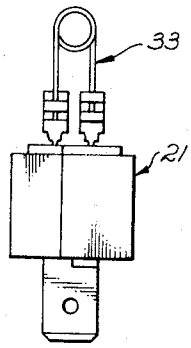
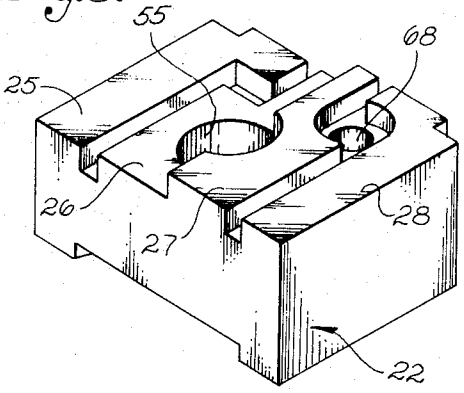


Fig. 4.

Fig. 5.



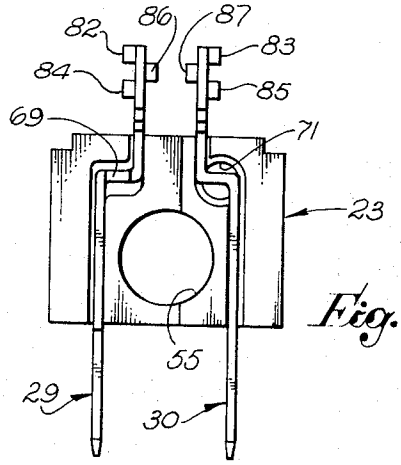


Fig. 7.

Fig. 15.

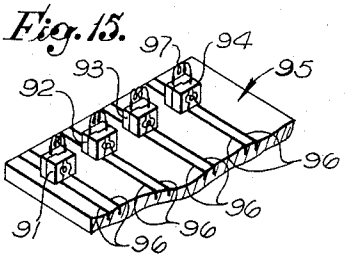


Fig. 6.

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Fig. 8.

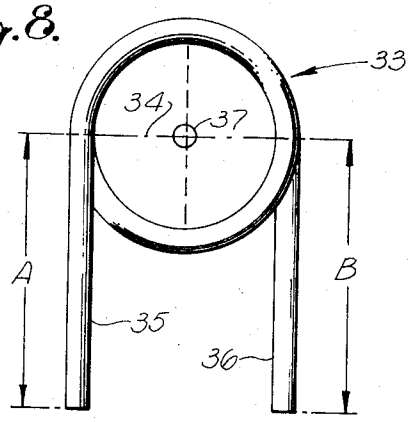


Fig. 9.

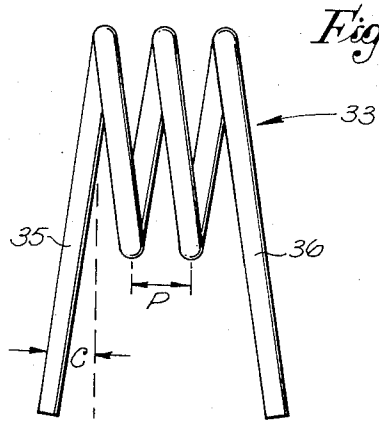
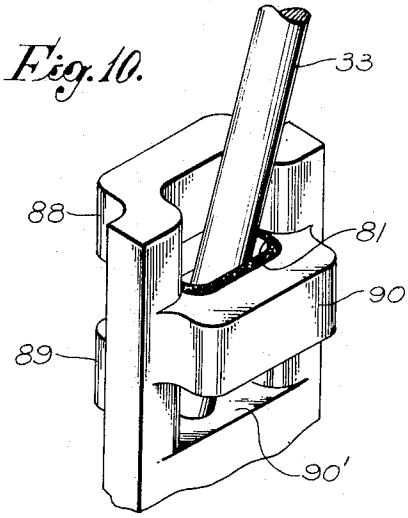


Fig. 10.



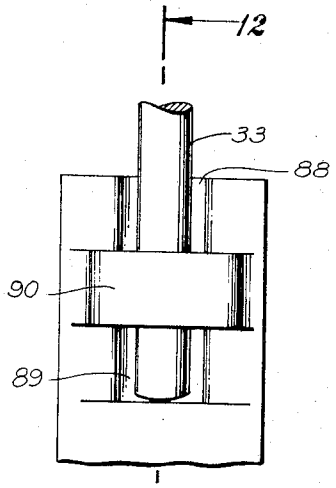


Fig. 11.

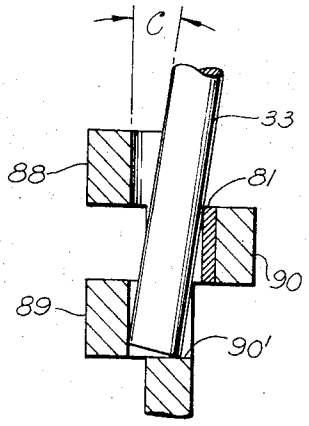
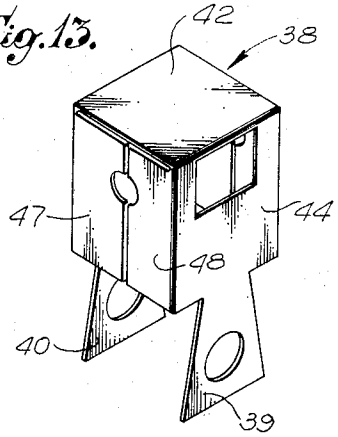


Fig. 12.

Fig. 13.



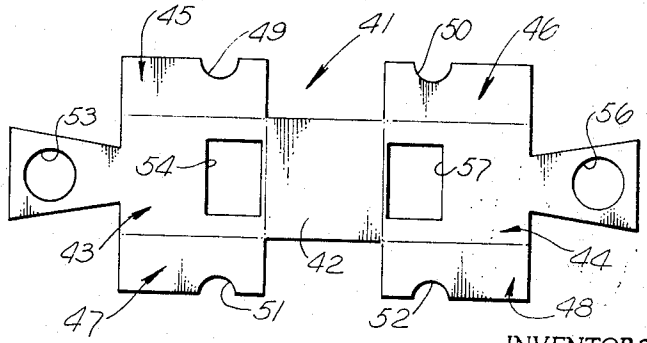


Fig. 14.

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ELECTRICAL IGNITION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to the art of heating a resistive wire to the ignition temperature of a gas fuel, and more particularly, to a resistance wire ignitor having an exceedingly long life, mounting or shielding means therefor, and a method of making the same.

In the past, it has been the practice to ignite the surface burners and oven pilot burners of a gas range by placing a coil of platinum wire adjacent a burner, and passing electric current through the wire of a magnitude sufficient to heat the gas to its ignition temperature.

Unfortunately, all suitable materials including platinum wire oxidize so badly in air that they have a useful life while being continuously heated of only about 3 days or less.

A wire made of molybdenum disilicide, $MoSi_2$, can be heated to the gas ignition temperature by passing current therethrough. When so heated continuously in air, the $MoSi_2$ wire has a useful life of in excess of 1 ½ years. However, $MoSi_2$ wire is very brittle and often breaks due to differential thermal expansion with its mounts and with shock, pressure and vibration.

Until the present invention, it was thought that $MoSi_2$ wire was so brittle that it could not be made or used in any form other than that of a straight wire. This, in itself, made the use of $MoSi_2$ wire disadvantageous. Unfortunately, such a wire, when employed as a resistance wire ignitor, must be heated to a maximum temperature, usually midway along its length, which is very high in order to provide reliable ignition of natural gas or the like. The very fact that a high wire temperature was required when $MoSi_2$ wire was used in a resistance wire ignitor even limited the useful life of that ignitor.

Due to differential thermal expansion between a $MoSi_2$ resistance wire ignitor and its mountings, expensive mountings were required. See U.S. Pat. No. 3,569,787.

In addition to the foregoing, all the resistance wire ignitors of the prior art required a large number of complicated and expensive component parts.

SUMMARY OF THE INVENTION

In accordance with the present invention, the above-described and other disadvantages of the prior art are overcome by providing a coiled wire made of $MoSi_2$.

Although it is unexpected, a way has been devised in which the brittle $MoSi_2$ wire can be wound into a helix of 2 ½ turns, the helix pitch and diameter being constant throughout its length. The wire has a circular corss section uniform throughout its length. The wire also extends beyond both helix ends the same distance, the extensions both being straight, the axis of each extension being tangent to the helix axis at its opposite ends.

Employing the helix with the extensions, as just described, and utilizing certain relative and/or absolute dimensions extraordinary advantages are derived.

In the first place, it was not expected that protection against the $MoSi_2$ wire breakage would result in providing a $MoSi_2$ wire wound in the shape of a helix. Although this was unexpected, it has, in fact, been found that the $MoSi_2$ wire, when wound in the shape of a helix, actually is more self-protective from breakage due to shock and vibration because the helix, even though

the wire itself is still brittle, acts as a coiled spring. Thus, the brittle character of the wire which made it so difficult to handle actually becomes an advantage when the wire is wound into a helix.

Another outstanding advantage of the present invention is that the wire, when wound in the shape of a helix, acts as a spring which can give with differential thermal expansion and, therefore, eliminate breakage thereupon due to the different thermal expansion coefficients of the helix and its mountings.

Still another outstanding advantage of the $MoSi_2$ helix is that it need not be heated to a temperature as high as that to which a straight $MoSi_2$ wire must be heated for reliable gas ignition. That is, the maximum temperature required at the point thereof along the helix for reliable gas ignition is substantially below that required of a single straight wire. For this reason, oxidation is reduced and the $MoSi_2$ helix of the present invention has a substantially longer life than any other resistance wire ignitor including, but not limited to, a straight $MoSi_2$ wire.

Still another outstanding advantage of the present invention resides in the elimination of voltage regulation equipment. In the past, when straight $MoSi_2$ resistance wires were used for gas ignition, it was necessary to operate the wire at such an extremely high temperature that voltage regulation was required to prevent the $MoSi_2$ straight wire from melting down or failing to ignite the gas. Regulation thus prevented the input voltage to the straight wire from falling too far due to an increase in current through the ignitor wire caused by a decline in the wire temperature. Wire temperature could thus be reduced by ventilation and gas ignition thereby prevented.

Reliable gas ignition by the $MoSi_2$ helix maintained at a lower temperature than the straight wire has been proven, wire temperatures in each case being measured by the use of the same optical pyrometer.

The advantage regarding voltage regulation is outstanding because voltage regulation may be completely eliminated by employing the $MoSi_2$ helix. The cost of special equipment required for voltage regulation in the prior art has, therefore, been eliminated in accordance with the invention.

It will be noted that all of the advantages described hereinbefore and some of the advantages described hereinafter were simultaneously derived from the manufacture of a coiled $MoSi_2$ wire helix. That is, not just one advantage was derived from this construction, but a great many outstanding advantages were derived simultaneously.

In accordance with another feature of the invention, the helix extensions extend generally in one direction and are located in electrical connector cups integral with prongs for a male electrical plug.

Another feature of the invention resides in spot welding or otherwise bonding a brazing compound inside each cup before the prongs and all of the metal structure connected therewith are formed. Thus, the prongs are mounted vertical in an oven filled with an inert or hydrogen gas or vacuum. A great many of the ignitors may thereby be batch brazed. The said helix extensions are mounted approximately vertically in the cups and flux applied to the helix extension and cup preparatory to mounting the substantially complete assembly in the oven. By this method, secure inexpensive mountings

are provided and bonded to the helix extensions. By using the batch braze, the process is inexpensive.

Another outstanding advantage of the present invention is that the metal of portions integral with the prongs and the prongs themselves are made of 310 stainless steel which has an annealing temperature about the same or somewhat below the brazing temperature of the brazing compound.

In accordance with the foregoing, the brazing step likewise produces an anneal which makes the prongs and their connections soft and pliable to further protect the brittle $MoSi_2$ helix from breakage due to shock and vibration, for example.

In accordance with the foregoing, the combined brazing and annealing step is economical.

Still a further feature of the invention resides in the use of a necked down portion in the prongs to permit the annealed, dead soft prongs to bend and thereby protect the brittle $MoSi_2$ helix in the event of a severe shock.

A further feature of the invention resides in the use of a snap-on wind shield for the ignitor. This shield is made from a single metal stamping. It is thus very economical to construct and to assemble. It requires no additional parts whatsoever for assembly. That is, for example, it requires no other fastening elements such as eyelets, screws, bolts, etc.

In accordance with the foregoing, the device of the present invention has a very small number of uncomplicated and inexpensive component parts.

The above-described and other advantages of the present invention will be better understood from the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a front elevational view of a completely assembled electrical resistance wire ignitor constructed in accordance with the present invention;

FIG. 2 is a side elevational view of the ignitor shown in FIG. 1;

FIG. 3 is a side elevational view identical to that shown in FIG. 1 with only a portion of the ignitor shield shown therewith in dotted lines;

FIG. 4 is a side elevational view of the assembly of FIG. 3 without any shield being shown therewith;

FIG. 5 is an enlarged perspective view of half of an insulator block shown in FIGS. 1, 2, 3 and 4;

FIG. 6 is a greatly enlarged perspective view of an electrical connector employed with the invention;

FIG. 7 is an enlarged elevational view of an assembly of the half of the insulator block shown in FIG. 5 with two electrical connectors identical to that shown in FIG. 6;

FIG. 8 is a greatly enlarged end elevational view of the resistance wire of the present invention through which current is passed to heat it up for gas ignition;

FIG. 9 is a side elevational view of the wire shown in FIG. 8;

FIG. 10 is a greatly enlarged perspective view of a partial assembly of the present invention, the enlargement being even greater than that shown in FIG. 6;

FIG. 11 is an elevational view looking at the assembly of FIG. 10 from the front as viewed therein;

FIG. 12 is a vertical sectional view through the assembly taken on the line 12—12 shown in FIG. 11;

FIG. 13 is a perspective view of the shield disassembled from the remaining portions of the ignitor of the present invention;

FIG. 14 is a top plan view of a metal stamping from which the shield of FIG. 13 is made; and

FIG. 15 is an assembly view of a plurality of ignitors without shields mounted on a refractory board preparatory to inserting the same into a hydrogen oven for performing the said batch braze, the resistance wires in FIG. 15 not yet being brazed to their corresponding electrical ignitors.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, an electrical ignitor is indicated at 20 having an insulator block 21 which may be used, more or less, as a base. Block 21 is split into two halves 22 and 23, shown in FIG. 2, along a line 24. Line 24 appears to be off center, and is, but blocks 22 and 23 are actually identical. Their mating surfaces, however, are staggered. The mating surfaces are indicated at 25, 26, 27 and 28 in FIG. 5, only one of the halves of block 21 being shown in FIG. 5.

As shown in FIG. 1, ignitor 20 includes electrical connectors 29 and 30 which are made of 310 stainless steel. Connectors 29 and 30 extend completely through block 21, and are fixed in position relative thereto by means to be described.

Connectors 29 and 30 have lower portions 31 and 32, respectively, which may be plugged into a conventional electrical receptacle to supply electrical current to a resistance wire ignitor 33, shown in FIG. 1. Wire 33 is made of $MoSi_2$. It is shaped in the form of a helix with a constant pitch and a constant diameter throughout its entire length. Wire 33 is circular in cross section throughout its complete length, and has a diameter constant throughout its complete length.

As shown in FIG. 8, the helix portion of wire 33 begins and ends in a plane perpendicular to the paper of the drawing through a line 34. To each end of the helix, extensions 35 and 36 are connected. That is, extensions 35 and 36 are merely portions of wire 33 and thus are integral with the portion thereof that is shaped in the form of a helix. Portions 35 and 36 have lengths A and B, respectively, where A is equal to B. Note will be taken that the axis of extension 35 is tangent to that portion of the axis of wire 33 which is shaped in the form of a helix. The point of tangency is thus midway between the inner and outer diameters of the helix on each side of the helix axis 37 and at different points in the said plane through line 34.

In FIG. 8, note will be taken that extensions 35 and 36, as viewed in FIG. 8, are absolutely vertical. However, this is not true in FIG. 9. Note that there is an angle C with the vertical in FIG. 9 that extension 35 makes due to the fact that the helix has a finite pitch and due to the fact that there is true tangency. The angle C is of substantially more than just passing interest, and its importance will be described hereinafter.

The ignitor 20, shown in FIG. 1, also has a shield 38 which is hollow, substantially square in horizontal cross section, except for two projections 39 and 40, integral therewith and shown in FIG. 13.

Shield 38 may be made from a single metal stamping of flat sheet material of a uniform thickness. Such a

stamping is shown at 41 in FIG. 14. A panel 42 provides the top of the shield 38, shown in FIG. 13. Also, the sides of shield 38 are identical. One side is provided by panel 43, the other being provided by the panel 44. Two panels 45 and 46 enclose another side and panels 47 and 48 enclose still another side. Cutouts 49 and 50 provide a substantially circular opening in panels 45 and 46, respectively, when the shield 38 is assembled. Similarly, cutouts 51 and 52 provide a circular opening in panels 47 and 48, respectively, when the shield 38 is assembled.

Panel 43 has circular and rectangular openings 53 and 54, respectively, therein, circular opening 53 being of a diameter equal to that of a larger circular hole 55 in block 21, shown in FIGS. 3, 5 and 7. Panel 44 has circular and rectangular openings 56 and 57, respectively, identical to openings 53 and 54, respectively.

Shield 38 may be snap fit on block 21. Block 21 has bosses 58 and 59, shown in FIG. 3. The surfaces of bosses 58 and 59, shown in FIG. 3, are flat and in the same plane, such plane being parallel to a flat surface 60. Boss 58 has straight portions 61 and 62 which are inclined with the same taper as the side edges of shield projections 39 and 40, shown in FIG. 13. The taper is more evident between lines 63 and 64, in FIG. 1. Similarly, boss 59 has flat surfaces 65 and 66. The surfaces of portions 61 and 62 lie in a single plane which is disposed at an angle relative to the single plane in which the surfaces of portions 65 and 66 lie.

Block 21 has a boss 67 which is substantially square, and which fits inside shield 38 shown in phantom at 38' in FIG. 3.

As shown in FIG. 3, block 21 has holes 68 and 71 on each side thereof. See also FIG. 5. Hole 68 in FIG. 5 extends completely through the half of the block shown in FIG. 5. However, when two halves are assembled, as shown in FIGS. 1, 2, 3 and 4, holes 68 and 71 do not become aligned. They do not lie in even partial registration. The hole 68 of the block half 22, not shown in FIG. 7, extends around a connector projection 69 whereas insulator block half 23, shown in FIG. 7, has a hole 71 corresponding to hole 68 which has an axis that is horizontally displaced from the axis of the hole 68, shown in FIG. 7. The hole 68 thus has an axis about midway between the vertical surfaces of projection 69 which lie in planes perpendicular to the paper, as viewed in FIG. 7. The axis of hole 71 is thus approximately in the center thereof, spaced substantially more than a hole diameter from that of hole 68 from projection 69.

In FIG. 5, note will be taken that surfaces 25 and 26 lie in the same plane. Similarly, surfaces 27 and 28 lie in the same plane. However, the plane of surfaces 25 and 26 is parallel to and below that of surfaces 27 and 28.

Connectors 29 and 30 are identical; however, they are oriented oppositely in FIG. 7. Further, only one connector will be described because they are identical. One such connector is shown in FIG. 6 having an end portion 72 formed in the shape of a compound wedge, a block portion 73 having a conventional hole 74 therethrough, a first intermediate portion 75, a second intermediate portion 76, a third intermediate portion 77, a fourth intermediate portion 78, a fifth intermediate portion 79 and an assembly 80. The connector shown in FIG. 6 is made from flat sheet stock. That is, both connectors are made of 310 stainless steel of a uniform thickness throughout its area. However, in accordance with one feature of the invention, a strip of brazing compound, shown at 81 in FIGS. 10 and 12, is spot welded or otherwise conventionally bonded to one side of the sheet material from which the connector is made.

Each connector is provided with a projection 82', projection 69 being identical thereto.

Another feature of the invention resides in the use of necked down portion 78 which, as will be described, when employed in a 310 stainless steel connector which has been annealed dead soft, provides shock proofing for the $MoSi_2$ wire 33.

Connectors 29 and 30 both have assemblies identical to assembly 80 and include, for example, as shown in FIG. 7, upper outside loops 82 and 83, lower outside loops 84 and 85 and middle loops 86 and 87. Loops 82, 84 and 86 are formed integrally with connector 29. Loops 83, 85 and 87 are formed integrally with connector 30.

Assembly 80, shown in FIG. 6, shows upper and lower outer loops 88 and 89, respectively. However, a small portion of a middle loop 90 may also be seen in FIG. 6.

In order to better understand the views of FIGS. 10, 11 and 12, inspection of the views of FIGS. 3 and 4 should be made noting especially the relationship between the wire 33 and the "cup" ends of connectors 29 and 30 where loops 82–87 are located. Note that loops 88, 89 and 90 generally form a cup having a flat bottom surface 90' where loop 89 has been broken out of the said sheet stock and where the lower end of wire 33 rests, as shown in FIGS. 10, 11 and 12.

A view of the left end of wire 33, as shown in FIG. 9, is shown in FIG. 8. A view of the right end of wire 33, shown in FIG. 9, would be identical to the view of FIG. 8. The offset of the halves of the block 21 produces an offset in the locations of the upper ends of the connectors. Some further offset is provided because necked down portion 78 is not in the center of portion 77, shown in FIG. 6. The horizontal spacing evident in FIG. 7 is simply produced because block 21 holds connectors 29 and 30 in that position, the corresponding holding slots for the connectors 29 and 30 being spaced apart.

For clarity, the reference numerals used in FIG. 6 are also employed in FIGS. 10, 11 and 12. Note in FIGS. 10, 11 and 12 that loops 88, 89 and 90 generally form a cup to receive an end of wire 33. Comparing FIGS. 3 and 9, note will be taken that, in the view of FIG. 3, extensions 35 and 36 of wire 33 are disposed at the same angle C relative to a plane transverse to the helix axis. This angle C is also shown in FIG. 12. Note that in FIG. 3, the upper end of connector 29 is actually closer to the viewer than the upper end of connector 30. This offset is provided, as aforesaid, by the offset in the halves of block 21 and in the offset of necked down portion 78 from portion 77 of the connector shown in FIG. 6. The offset is desirable to be able to insert the lower ends of wire 33 into the connector cups without stressing the wire 33. This not only prevents damage or breakage of wire 33 during assembly and during further processing, but also provides a shock proof mounting for wire 33.

The reason for one offset is that wire extension 35 is inclined downwardly, as viewed in FIG. 3, at the rear of the helix, and extension 36 is inclined downwardly

in front. Thus, the reason that extensions **35** and **36** are offset in approximately perpendicular directions is that extensions **35** and **36** are tangent to the helix portion of wire **33** at the ends thereof on opposite sides thereof.

Notwithstanding the foregoing, it is an advantage that, as shown in FIGS. **4** and **8**, extensions **35** and **36** lie generally in vertical parallel planes tangent to an external cylindrical surface that outlines the helix. Thus, even though the end of wire **33** comes into the cup at angle C, as shown in FIG. **12**, looking at it the other way as in FIG. **11**, it goes in straight and can thereby make good contact with brazing compound **81**, as shown in FIG. **12**.

FIGS. **10**, **11** and **12** actually illustrate an assembly step in the method of the invention of making the ignitor **20**. In the manufacture of the invention, connectors **29** and **30** are assembled in between block halves **22** and **23**, as shown in FIGS. **2** and **7**. If desired, sauereisen or any other conventional refractory or insulator cement may be placed upon the surface facing the viewer in FIG. **7**.

With the block halves **22** and **23** and connectors **29** and **30** assembled and connectors **29** and **30** located in the block grooves and in the positions shown in FIG. **7**, cement may be inserted into holes **68** and **71**, as shown in FIGS. **3** and **7**, respectively. This step may be used with or without the previously described step of applying cement. The same is true of the said previously described step.

After the cement has dried, plugs **91**, **92**, **93** and **94** are "plugged into" a refractory board **95**, as shown in FIG. **15**. Portions **31** and **32** and portions corresponding thereto, as shown in FIG. **1**, thus extend down into one of eight grooves **96** in board **95**. The portion of board **95** between the closest immediate adjacent two of the grooves **96** may be slightly wider than the space between portions **31** and **32** so that there is a tight or snug fit of the connectors on each side of the two immediate adjacent grooves **96**. Alternatively, each groove may be slightly thinner than the thickness of each of the portions **31** and **32** so as to allow for a snug or tight fit of the portions **31** and **32** in respective corresponding slots **96**.

After plugs **91**, **92**, **93** and **94** have been plugged into board **95**, wires identical to wire **33** are then assembled therewith as indicated, for example, at **97**. Each end of the resistance wire of the $MoSi_2$ wire ignitor is placed in a cup of a corresponding connector in the manner illustrated in FIGS. **10**, **11** and **12**. Now, brazing compound **81** is located contiguous to wire **33**, as shown in FIG. **12**. This is true of the cup of each connector. High temperature brazing flux is applied to each cup area. Board **95** is then placed in a hydrogen or vacuum oven.

The composition of the brazing compound **81** is **18** percent nickel and **82** percent gold. A good bond could be made by raising the temperature of the oven to about 1,800° F. However, there is another advantage with the use of this temperature. The use of this temperature causes a dead soft anneal of the 310 stainless steel connectors. Thus, the oven temperature is raised to 1,800° F. for a period of about 5 minutes. The completed assemblies may be allowed to cool in air and are ready for use immediately thereafter. However, a wind shield is helpful to keep the temperature of wire **33** constant in use. Thus, after shield **38** is fabricated, as shown in FIG. **13**, it can be simply snapped over insulator block **21** in the position shown in FIG. **2** with portions **39** and **40** snuggly fitted in the channels defined between the surfaces of straight portions **61**, **62**, **65** and **66** on both halves of the insulator block **21**.

Wire **33** may have any diameter, but preferably should be as small as possible for a high resistance, efficient heating and low operating temperature. On the other hand, if wire **33** is too small in diameter, it will be even more likely to break due to any small shock or vibration. A wire diameter of 0.016 inch has been found satisfactory and is preferable in the circumstances.

The inside diameter of the helix, as shown in FIG. **8**, preferably is between about 0.12 inch and 0.13 inch. The pitch of the helix, as indicated at P in FIG. **9**, preferably is between about 0.036 inch and 0.046 inch.

The helix preferably has at least 1 ½ turns and has an odd number of half turns. However, at least 2 ½ turns have been found more satisfactory.

In accordance with the foregoing, it will be appreciated that the helix inside diameter is preferably between about 7 to 9 times as large as the diameter of the wire. Further, the helix pitch must be larger than the wire diameter, and preferably is less than 3 times as large as the wire diameter. More efficient heating can be expected if these limits are retained. The same is true of lower wire temperature.

Preferably, a voltage is applied between connectors **29** and **30** which is adequate to heat one point on the wire **33** to a predetermined temperature larger than the temperature at any other point thereon, wherein said predetermined temperature is between about 1,900° F. and 2,400° F. Reliable ignition may then be achieved with a maximum wire life.

Although a hydrogen oven has been described, it is to be understood that any oven may be employed. However, preferably, the oven is filled with an inert gas including, but not limited to, nitrogen. A vacuum may also be used.

The phrase "inert gas" is hereby defined herein as including a gas which does not react with the materials placed in the oven in a deleterious way.

Reduction may be anticipated if hydrogen is used. This is an advantage of hydrogen over some other gases. However, nitrogen may be used, if desired. Inert gas is employed to reduce or eliminate oxidation. Oxidation can occur on the connectors **29** and **30**, the brazing compound **81** and the wire **33**.

Due to the fact that the batch braze is performed at an oven temperature of 1,800° F., a dead soft anneal of the connectors **29** and **30** is effected because the dead soft annealing temperature of 310 stainless steel is about 1,775° F.

The phrase "dead soft" is hereby defined herein as describing a material or metal which has been annealed to an extent such that it cannot be made any softer to any substantial extent by any kind of further annealing.

Although board **95**, shown in FIG. **15**, may be made of any desirable refractory material, insulating material or a material of a low specific heat, transite may be preferable because of its low specific heat. Further, board **95** need not be made of a refractory material if it has a low specific heat and will stand a temperature of about 1,800° F. for about 5 minutes.

Although outstanding features of the invention are achieved by the use of wire **33** when it is formed at a helix, many features of the invention are not limited to this particular geometric configuration.

Wire ignitor **33** may be formed by heating it to a temperature between about 2,900° F. and 3,000° F. and winding the same on a cylindrical carbon mandrel. Preferably, both the wire and the mandrel are so heated. Heating may be done by the use of three gas torches located in positions equally spaced around the mandrel, the torches being located substantially in a single plane and directed radially inwardly toward the mandrel axis.

Another feature of the invention resides in the use of holes **53** and **56**, shown in FIG. **14**, in alignment with hole **55**. A bolt may be inserted therein for mounting purposes, if desired.

The phrase "dead soft annealing temperature" is hereby defined as that temperature above which a metal can be raised, but by the annealing thereof, it cannot be made any softer.

The phrase "brazing temperature" is hereby defined herein as that temperature to which brazing compound **81** or an equivalent thereof must be raised in order to accomplish a suitable braze.

In the brazing step, the use of flux may be helpful in attaining suitable wetting of the materials and in preventing oxidation, if desired.

Note will be taken that it is an outstanding advantage of the invention that plugs **91, 92, 93** and **94** may be oriented, as shown in FIG. **15**, with all of the connectors extending in an upward vertical direction to easily hold the lower ends of the $MoSi_2$ resistance wire ignitors for the braze, yet holding the wire ignitors without stressing the same.

Wire **33**, when it is first made straight, may be made by any conventional means or method and will be found to have generally a resistivity of 100 ohm circular mils per foot. It may be identical to Kanthal Super ST made by the Kanthal Corporation, if desired. The voltage applied between connectors **29** and **30** will generally be about 2.6 volts. With this voltage, when the ambient temperature is approximately 70° F., the wire will carry a current of approximately 3.6 amperes.

As stated previously, it is one outstanding advantage of the present invention that for reliable gas ignition, the wire ignitor **33** of the present invention can operate at a lower temperature than a straight wire can. This is unexpected, but, after considerable study, can perhaps now be explained in that reliable gas ignition can be obtained with different peak wire temperatures. "Peak temperature" is thus hereby defined as the temperature along the length of a wire which is the highest. Note will be taken that the temperature along the wire varies with the length of the wire from connector **29** to connector **30**. The peak temperature is likely to be at, or close to, the midpoint to the ends of the wire. In a straight wire, due to a cooling effect by the heat conduction of the connectors **29** and **30**, the total resistance of the wire increases nonlinearly with temperature to such an extreme extent that a voltage regulator must be provided for a straight $MoSi_2$ wire ignitor. On the other hand, when the wire is formed into the helix, the adjacent turns of the helix apparently heat each other and form a "box" inside of which air or gas is heated efficiently. Moreover, the wire of the helix has a more uniform temperature along its length than does a straight wire ignitor. That is, the temperature is not precisely uniform, but it is more uniform because of the mutual heating of adjacent turns. For this reason, the resistance between the connectors through the wire of a $MoSi_2$ helix varies much more linearly with temperature. Self-regulation is thus produced which does not require additional or more expensive apparatus for accomplishing voltage regulation. In other words, the helix wire ignitor of the present invention with a conventional low cost transformer may be substituted for a $MoSi_2$ straight resistance wire ignitor and a transformer incorporating means for regulating the wire ignitor voltage.

In accordance with the foregoing, it will be appreciated that although coiled resistance wire ignitors are old in the art, a great many outstanding advantages are achieved by practicing the present invention and the use of a $MoSi_2$ helical resistance wire ignitor is not obvious because no one suspected that it could even be wound into a helix, $MoSi_2$ being a very brittle material. It is so brittle, it may be broken with approximately the same force as used in breaking pencil lead for automatic pencils.

Note will be taken that the brittle character of the $MoSi_2$ is, in fact, used because its brittle character makes it a better spring and therefore, in the shape of a helix, more shock and vibration resistant.

It is an outstanding advantage of the present invention that for reliable gas ignition, the peak temperature of the helical $MoSi_2$ wire of the present invention is substantially lower than that of a straight wire. This means that the wire ignitor of the present invention has a life longer than even a straight $MoSi_2$ wire.

It is an advantage of the present invention that the portions of connectors **29** and **30** above the portions thereof identical to necked down portion **78** shown in FIG. **6** and connected to wire extensions **35** and **36** have a mass greater than that of wire **33**. Thus, if connectors **29** and **30** are dead soft, a shock will cause connectors **29** and **30** to bend at the said necked down portions thereof and protect wire **33** from damage or breakage.

One definition of the phrase "yield point" for use herein and for use in the claims is the stress or force at which a structure reaches its elastic limit.

One definition for use herein and for use in the claims for the phrase "elastic limit" is the greatest stress or force a structure can sustain without causing permanent strain after release of stress.

The foregoing and the following may coincide with or slightly vary with different definitions set forth in the prior art.

As is well known, a structure is frequently described as having taken a "plastic deformation" after having exceded the elastic limit thereof.

One definition for use herein and in the claims for the phrase "rupture strength" is the stress or force at the point of breaking of a structure. The phrase "rupture strength" may or may not mean exactly the same thing as "breaking stress" or "breaking force."

The series of volumes of *Encyclopedia of Science and Technology* (McGraw-Hill Book Company, New York, copyright 1960, 1966, 1971) contains considerable matter including definitions the same as or similar to those set forth herein. However, many of these definitions, of course, are old, old concepts known in the art for many, many years. However, for convenience, some small portions of said series are quoted hereinafter.

In Volume 4 of the same series, page 472, under the subtitle "Elastic Limit," in bold type, the following sentence appears: "The greatest stress a material can sus-

tain without notable permanent strain after release of stress."

In Volume 3 of the said series, page 202, the following is found: "Strains completely recoverable on removal of stress are called elastic strains. Above a critical stress, both elastic and plastic strains exist, and that part remaining after unloading represents plastic deformation called inelastic strain," (underline added).

In Volume 3 of the said series, page 203, the following is found: "Ultimate strength in engineering application refers to stress at maximum load resisted. For brittle materials, it is the breaking stress."

What is claimed is:

1. Electrical ignition apparatus comprising: first and second spaced electrical conductors; means fixed to both of said conductors holding them in fixed and insulated positions relative to each other, said conductors both having portions projecting beyond one side of said means, each of said conductors being made of a dead soft material and having a necked down intermediate portion separating said projection portion from a remaining portion; and a resistance wire ignitor having first and second ends conductively bonded to said first and second conductor projecting portions, respectively, said wire being more brittle than platinum, said wire being made of a material having an electrical resistivity substantially larger than that of the material of which said conductors are made.

2. The invention as defined in claim **1**, wherein said wire is a coil in the form of a helix, said first and second ends of said coil wire being straight extensions of said helix, said extensions being essentially tangent to the cylindrical surface of said helix.

3. The invention as defined in claim **1**, wherein said wire is formed in the nature of a helix.

4. Electrical ignition apparatus comprising: first and second spaced electrical conductors; an insulator block fixed around both of said conductors holding them in fixed and insulated positions relative to each other, said conductors both having portions projecting beyond one side of said means; a resistance wire ignitor having first and second ends conductively bonded to said first and second conductor projecting portions, respectively, said wire having an electrical resistivity substantially larger than that of either of said conductors; and a wind shield mounted on said block in a position extending around said ignitor, said shield having at least one opening therein to allow a combustible fuel to pass therethrough to a position contiguous to said ignitor, said block having approximately parallel opposite flat faces, said shield having a body and two leaf spring projections snap fit on said faces, respectively, said leaf spring projections being fixed relative to said body.

5. The invention as defined in claim **4**, wherein said leaf spring projections are substantially flat, each of said faces having a boss on each side forming a channel, each channel having a taper and decreasing in width toward said ignitor, said leaf spring projections being positioned in said channels, respectively, said leaf spring projections having a taper to mate with its corresponding channel, said shield body portion being positioned contiguous to said bosses when said leaf spring projections are located contiguous to said bosses so as to trap said shield on said block.

6. The invention as defined in claim **5**, wherein said leaf spring projections fit contiguous to said block faces when said leaf spring projections are unstressed.

7. The invention as defined in claim **6**, wherein said leaf spring projections are integral with said shield body.

8. The invention as defined in claim **7**, wherein said shield body and said leaf spring projections are made of a single sheet metal stamping.

9. The invention as defined in claim **8**, wherein said block has a mounting hole extending completely therethrough, each of said leaf spring projections having a hole therethrough positioned in alignment with said block hole.

10. Electrical ignition apparatus comprising: first and second spaced electrical conductors; means holding both of said conductors respectively in substantially fixed and insulated positions relative to each other and in substantially fixed positions relative to said means, each of said conductors having a portion projecting from said means; and an ignitor including a resistance wire having first and second ends conductively bonded at first and second respective points to said first and second conductor projecting portions, respectively, said wire being brittle and subject to breakage when it is subjected to moderate to low shock or other loads, said wire being made of a material having an electrical resistivity substantially larger than that of the material of which said conductors are made, at least the said portion of said first conductor having a part that has a cross section small enough, is made of a material, and has a yield point such that said wire will not exceed its rupture strength, i.e. will not break, when said first conductor is subjected to a shock load having a component normal thereto of a magnitude sufficiently large to cause a predetermined inelastic strain to be produced in the said part of the portion of said first conductor and to cause the part of the portion of said first conductor to exceed its elastic limit, i.e. to take a permanent plastic deformation of said predetermined magnitude, to take a permanent set, and to fail to recover its original shape, the energy absorbed by the part of said portion of said first conductor in exceeding its elastic limit reducing the energy transmitted to said wire via said first conductor and reducing the load upon said wire.

11. The invention as defined in claim **10**, wherein said first and second conductor portions are longitudinal in shape, said means having a flat side, both of said conductor portions projecting from the same said flat side of said means in respective directions parallel to each other, the said second conductor portion having a part the same as that of said first conductor portion, said parts being spaced the same distance from the said flat side of said means, said parts including respective necked down pieces of the respective conductor portions of which said parts are respectively integral, said first and second conductor portions projecting the same distance from said means flat side, both of said parts being dead soft.

12. The invention as defined in claim **10**, wherein the said portion of the said second conductor has a part similar to the part of the portion of said first conductor.

13. The invention as defined in claim **12**, wherein said parts include respective necked down pieces of the respective conductor portions of which said parts are respectively integral.

14. The invention as defined in claim **13**, wherein said first conductor has an approximately straight first partial length from the part of said first conductor portion to the said first point, said second conductor hav-

ing an approximately straight second partial length from the part of said second conductor portion to the said second point; said first and second partial lengths being approximately parallel.

15. The invention as defined in claim **14,** wherein both of said parts are respectively made of dead soft materials.

16. The invention as defined in claim **12,** wherein said first conductor has an approximately straight first partial length from the part of said first conductor portion to the said first point, said second conductor having an approximately straight second partial length from the part of said second conductor portion to the said second point; said first and second partial lengths being approximately parallel.

17. The invention as defined in claim **16,** wherein both of said parts are respectively made of dead soft materials.

18. The invention as defined in claim **12,** wherein both of said parts are respectively made of dead soft materials.

19. The invention as defined in claim **18,** wherein said parts include respective necked down pieces of the respective conductor portions of which said parts are respectively integral.

20. The invention as defined in claim **10,** wherein the said part of said first conductor portion includes a necked down piece of said first conductor integral therewith.

21. The invention as defined in claim **20,** wherein the said part of said first conductor portion is made of a dead soft material.

22. The invention as defined in claim **10,** wherein the said part of said first conductor portion is made of a dead soft material.

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